**VERDIGRIS BASIN TOTAL MAXIMUM DAILY LOAD**

**Waterbody: Fall River**
**Water Quality Impairment: Dissolved Oxygen**

## 1. INTRODUCTION AND PROBLEM IDENTIFICATION

**Subbasin:** Fall River **County:** Greenwood, Butler and Chase

**HUC 8:** 11070102

**HUC 11** (HUC 14s)**:** **010** (010, 020, 030, 040, 050, 060, 070 and 080)

**Drainage Area:** 334.2 square miles

**Main Stem Segments:** WQLS: 8* and 9* (Fall River) starting at confluence with Otter Creek and traveling upstream to headwaters in north-central Lyon County (**Figure 1**).

** An error was made in the omission of main stem segments 8 and 9 from the 1998 303(d) list for DO impairment.*

**Tributary Segments:**

| | | |
|---|---|---|
| WQLS: | Spring Creek (12) | |
| | | Kitty Creek (27) |
| | | Burnt Creek (24) |
| | W. Br. Fall River (11) | |
| | | Coon Creek (25) |
| | | Ivanpah Creek (19) |
| Non-WQLS: | Otis Creek (20) | |
| Non-WQLS: | Battle Creek (18) | |
| WQLS: | E. Br. Fall River (635)** | |
| | | Oleson Creek (21) |
| | | Swing Creek (989) |

*** An error was made in the omission of tributary segment 635 from the 1998 303(d) list for DO impairment* **(Figure 1)**.

**Designated Uses:** Special Aquatic Life Support, Primary Contact Recreation, Domestic Water Supply; Food Procurement; Ground Water Recharge; Industrial Water Supply Use; Irrigation Use; Livestock Watering Use for Main Stem Segments (8 and 9) and Tributary segment 11 and 635 (East and West Br. Fall River).

Expected Aquatic Life Support and Secondary Contact Recreation on Kitty, Burnt, Coon, Ivanpah, Oleson and Swing Creeks (27, 24, 25, 29, 21 and 989, respectively).

**1998 303(d) Listing:** Table 1 - Predominant Non-point Source and Point Source Impacts

**Impaired Use**: Expected Aquatic Life Support

**Water Quality Standard**: Dissolved Oxygen (DO): 5 mg/L (KAR 28-16-28e(c)(2)(A))

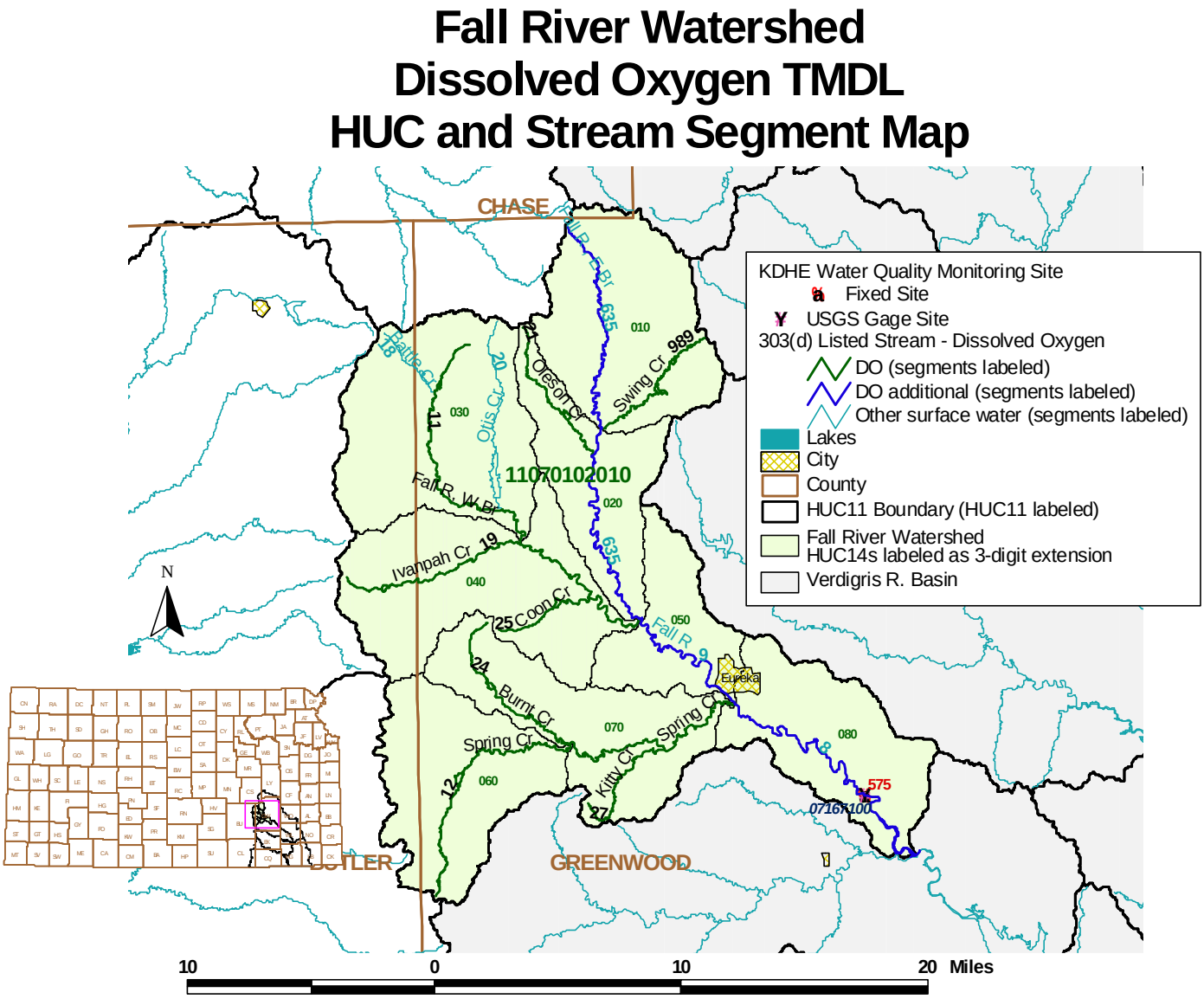



**Figure 1**

## 2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

**Level of Support for Designated Use under 1998 303(d):** Not Supporting Aquatic Life

**Monitoring Sites:** Station 575 near Climax

**Period of Record Used:** 1990-2000 for Station 575; 1999 includes some Kansas Biological Survey Data (**Figure 2**)

**Flow Record:** Otter Creek at Climax (USGS Station 07167500) matched to Fall River near Climax (USGS Station 07167100).

**Long Term Flow Conditions:** 10% Exceedance Flows = 360 cfs, 95% = 0.05 cfs

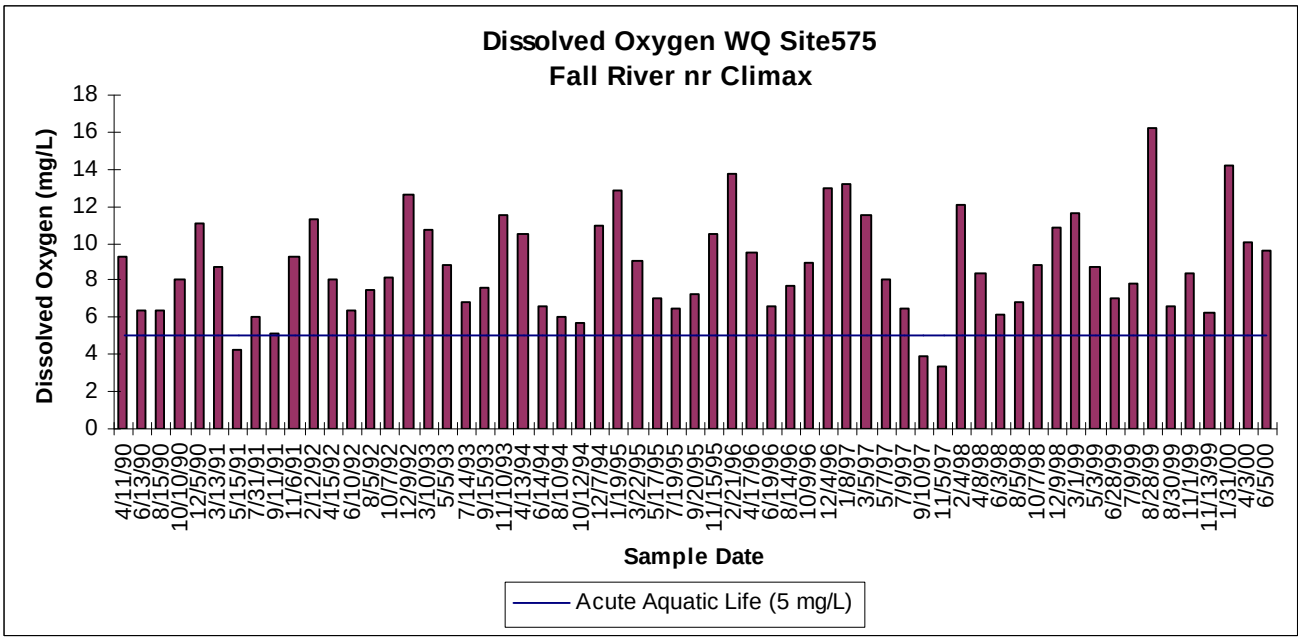



**Figure 2**

**Current Conditions:** Since loading capacity varies as a function of the flow present in the stream, this TMDL represents a continuum of desired loads over all flow conditions, rather than fixed at a single value. Sample data for the sampling site were categorized for each of the three defined seasons: Spring (Apr-Jul), Summer-Fall (Aug-Oct) and Winter (Nov-Mar). High flows and runoff equate to lower flow durations; baseflow and point source influences generally occur in the 75-99% range. Load curves were established for the Aquatic Life criterion by multiplying the flow values for Fall River near Climax along the curve by the applicable water quality criterion and converting the units to derive a load duration curve of pounds of DO per day. This load curve graphically displays the TMDL since any point along the curve represents water quality at the standard at that flow. Historic excursions from water quality standards (WQS) are seen as plotted points *below* the load curves. Water quality standards are met for those points plotting *above* the applicable load duration curves (**Figure 3**).

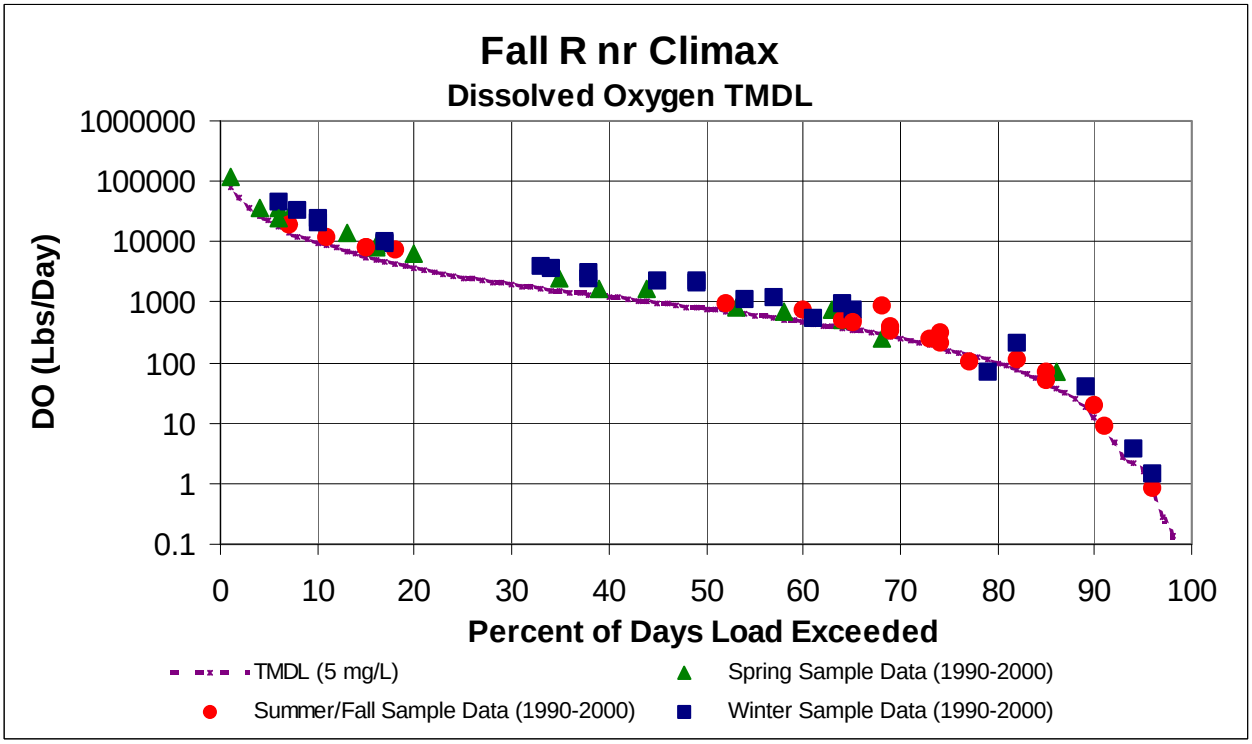



**Figure 3**

An excursion was seen in each of the three seasons and is outlined in **Table 1**. Six percent of the Spring samples and 4% of Summer-Fall samples were below the aquatic life criterion. Four percent of the Spring samples were under the aquatic life criterion. Overall, 5% of the samples were under the criterion. This would represent a baseline condition of full support of the impaired designated use.

**Table 1**
**NUMBER OF SAMPLES UNDER DISSOLVED OXYGEN STANDARD OF 5 mg/L BY FLOW**

| Station | Season | 0 to 10% | 10 to 25% | 25 to 50% | 50 to 75% | 75 to 90% | 90 to 100% | Cum Freq. |
|---|---|---|---|---|---|---|---|---|
| Fall River near Climax (575) | Spring | 0 | 0 | 0 | 1 | 0 | 0 | 1/18 = 6% |
| | Summer | 0 | 0 | 0 | 0 | 1 | 0 | 1/23 = 4% |
| | Winter | 0 | 0 | 0 | 0 | 1 | 0 | 1/23 = 4% |

No DO violations have been encountered at flows exceeding 11.0 cfs on the Fall River near Climax, therefore a critical low flow can be identified on the Fall River as those flows of 11 cfs or less.

A watershed comparison approach was taken in developing this TMDL. The Otter Creek near Climax watershed (Water Quality Sampling Site 574 in the watershed was not impaired by low DO) which is smaller than the Fall River watershed, has similar land use characteristics (**see Table 2 in Appendix**) and is located immediately south of the Fall River watershed. The relationship of DO to ammonia, biochemical oxygen demand (BOD), fecal coliform bacteria (FCB), water temperature, turbidity, nitrate, phosphorus, pH and total suspended solids (TSS) were used in the comparison.

**Table 3 in the Appendix** outlines those water quality data for the samples taken on the same day for the two sites of interest. **Table 4 in the Appendix** is the subset of data from Table 3 for those sample dates when DO was below the aquatic life criterion for sample site 575. From Table 4 all parameters were comparable. Based on this comparison, it is likely that low flow is the primary factor influencing the few DO violations in the Fall River watershed.

**Desired Endpoints of Water Quality (Implied Load Capacity) at Site 575 over 2007 - 2011**

The desired endpoint will be a biochemical oxygen demand from artificial sources such that the current average BOD concentrations remain below 2.6 mg/l in the stream under the critical flow conditions which results in no excursions below 5 mg/l of DO detected between 2007 - 2011 attributed to these sources.

This desired endpoint should maintain DO concentrations in the creek at the critical lower flows (0 - 11 cfs). Seasonal variation is accounted for by this TMDL, since the TMDL endpoint is sensitive to the low flow usually occurring in the June - November months.

This endpoint will be reached as a result of expected, though unspecified, reductions in organic loading from the various sources in the watershed resulting from implementation of corrective actions and Best Management Practices, as directed by this TMDL (see Implementation - Section 5). Sediment control practices such as buffer strips and grassed waterways should help reduce the non-point source BOD load under higher flows which, in turn, should help reduce the oxygen demand exerted by the sediment transported to the stream that may occur during the critical flow period. Achievement of this endpoint will provide full support of the aquatic life function of the creek and attain the dissolved oxygen water quality standard.

## 3. SOURCE INVENTORY AND ASSESSMENT

**NPDES:** There is one NPDES permitted wastewater discharger within the watershed (**Figure 4**). This system is outlined below in **Table 2**. The Christian Hill Camp facility has a non-discharging lagoon that may contribute an organic substance load to Segment 12 of Spring Creek under extreme precipitation events (flow durations exceeded under 5 percent of the time). Such events are not even remotely related to the flow conditions associated with the DO violations in this watershed.

**Table 2**

| DISCHARGING FACILITY | STREAM REACH | SEGMENT | DESIGN FLOW | TYPE |
|---|---|---|---|---|
| Eureka WTF | Fall R. (via unnamed trib.) | 3 | 0.282 mgd | Lagoon |

The population projection for Eureka to the year 2020 indicate modest declines. Projections of future water use and resulting wastewater appear to be within the design flows for of the current system's treatment capacity. Examination of 1998, 1999, 2000 and 2001 effluent monitoring of the city of Eureka indicates the city has rarely exceeded its permit limit and is usually well below that limit. Based on the low frequency of DO violations in the watershed, it is concluded that observance of current BOD permit limits for the city of Eureka is sufficient to maintain DO levels above the current criterion.

# Fall River Watershed
# NPDES Sites and Livestock Waste Management Facilities

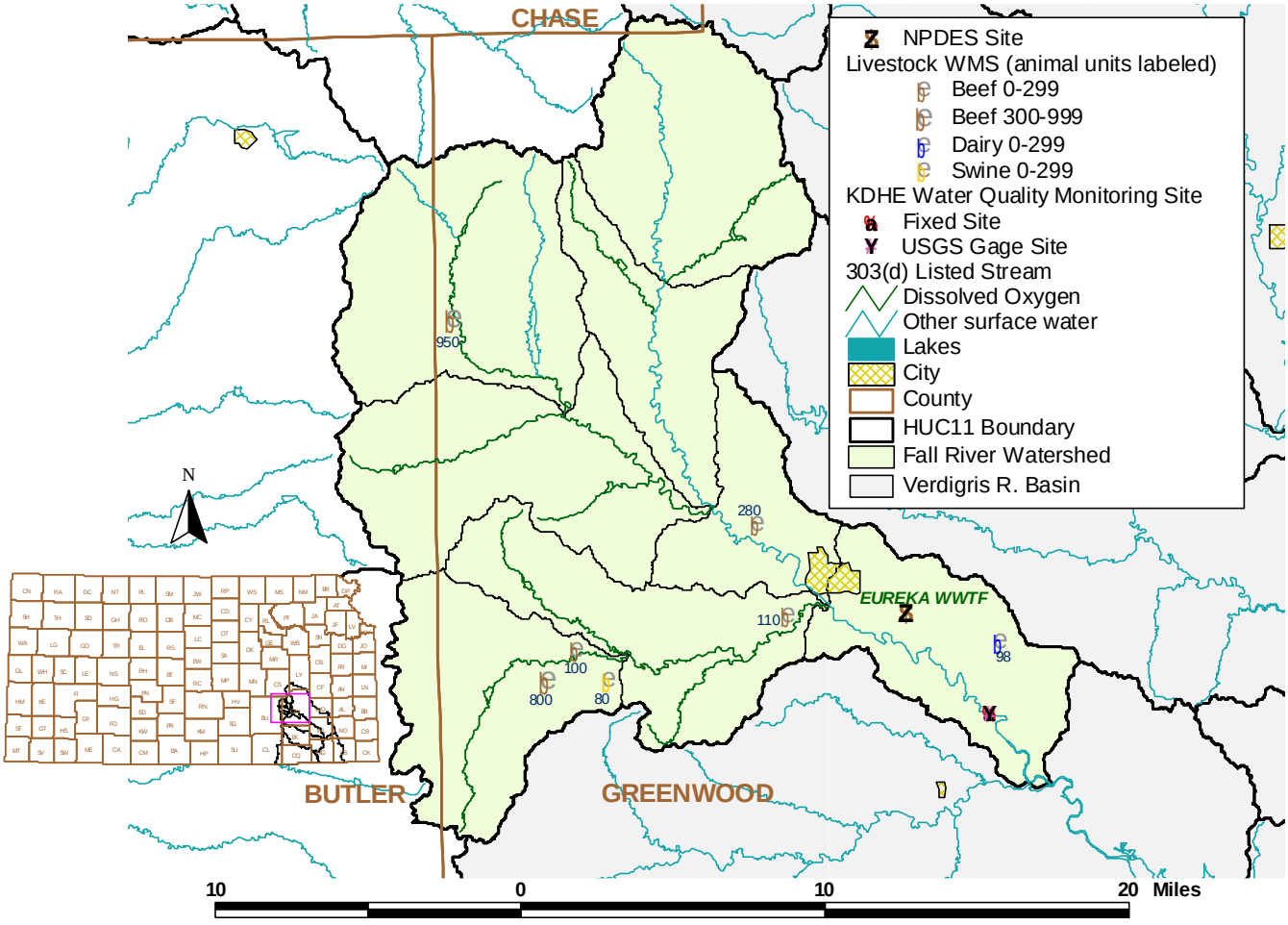
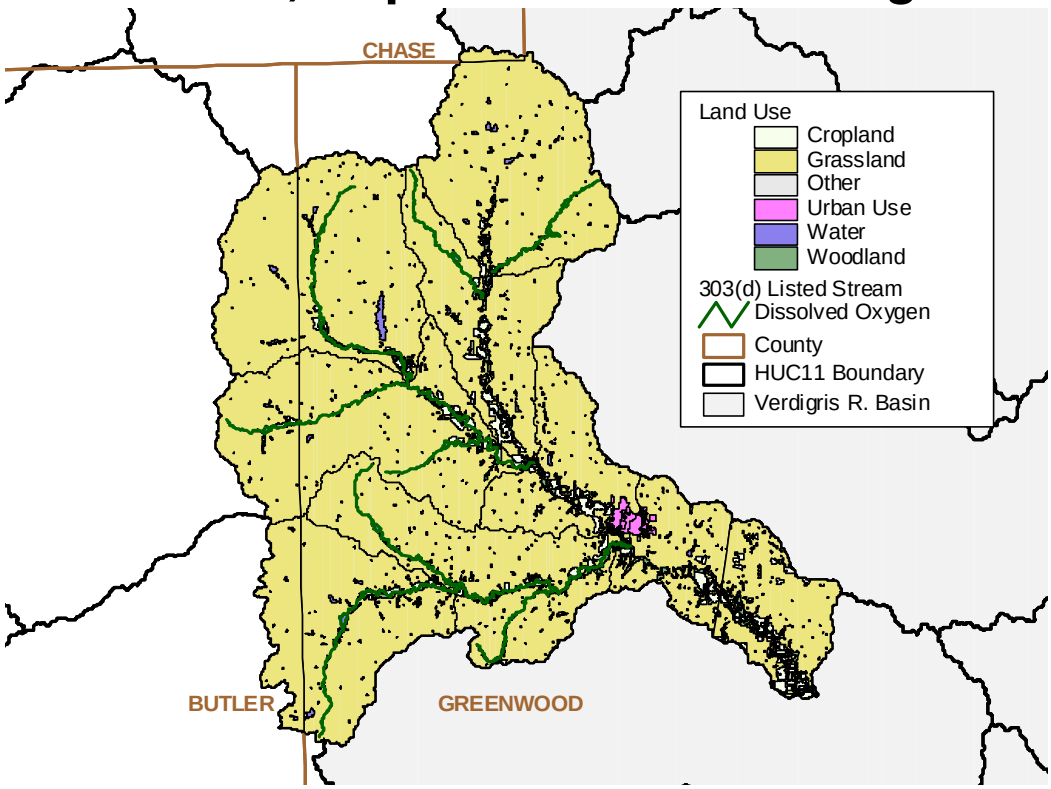



**Figure 4**

**Livestock Waste Management Systems**: Seven operations are registered, certified or permitted within the watershed. These facilities (mostly beef) are located in the lower half of the watershed(**Figure 3**). All permitted livestock facilities have waste management systems designed to minimize runoff entering their operations or detaining runoff emanating from their areas. Such systems are designed for the 25 year, 24 hour rainfall/runoff event, which typically coincide with stream flows exceeded less than 1 - 5 % of the time. NPDES permits, also non-discharging, are issued for facilities with more than 1,000 animal units. None of the facilities in the watershed are of this size. Potential animal units for all facilities in the watershed total 2,418. The actual number of animal units on site is variable, but typically less than potential numbers.

**Land Use**: Most of the watershed is grassland (93% of the area), cropland (3%), or woodland (2%). Most of the cropland is located along the main stem of the watershed. The grazing density estimate is average in the watershed when compared to densities elsewhere in the Verdigris Basin (32-39 animal units/mi$^2$) (**Figure 5 and Table 2 in the Appendix**).

# Fall River Watershed
# Land Use, Population and Grazing Density



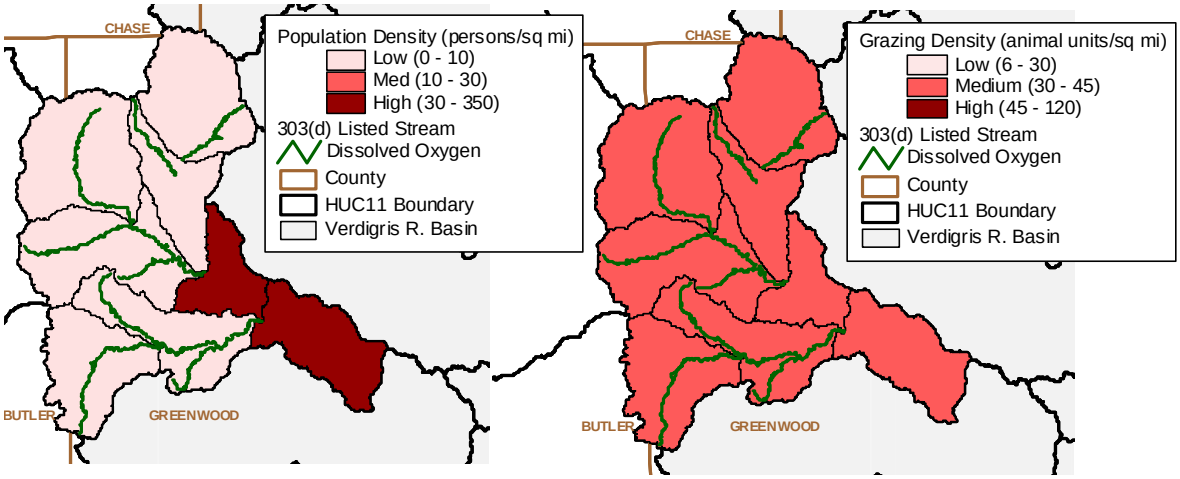




**Figure 5**

**On-Site Waste Systems**: The watershed's population density is low (1 - 3 persons/mi$^2$) in the upper two thirds of the watershed and high (43-59 person/mi$^2$) in the lower third when compared to densities across the Verdigris Basin (**Figure 5**). The rural population projections for Greenwood and Butler counties through 2020 show significant growth (29-37% increase, respectively). While failing on-site waste systems can contribute oxygen demanding substance loadings, their impact on the impaired segments is generally limited, given the smaller size of the rural population and magnitude of other sources in the watershed.

**Contributing Runoff**: The Fall River watershed's average soil permeability is 0.4 inches/hour according to NRCS STATSGO data base. All of the watershed produces runoff even under relatively low (1.71"/hr) potential runoff conditions. Under very low (1.14"/hr) potential conditions, this potential contributing area is reduced to about 96%. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As the watersheds' soil profiles become saturated, excess overland flow is produced. Generally, storms producing less than 0.57"/hr of rain will still generate runoff from 84% of this watershed, chiefly from the upper and lower third of the watershed and along the stream channels.

**Background Levels:** Some organic enrichment may be associated with environmental background levels, including contributions from wildlife and stream side vegetation, but it is likely that the density of animals such as deer is fairly dispersed across the watershed and that the loading of oxygen demanding material is constant along the stream. In the case of wildlife, this loading should result in minimal loading to the streams below the levels necessary to violate the water quality standards. In the case of stream side vegetation, the loading should be greater in the Upper half of the watershed or along the main stem with its larger proportion of woodland near the stream.

## 4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

BOD is a measure of the amount of oxygen required to stabilize organic matter in a stream. As such, BOD is used as a benchmark measure to anticipate DO levels while it measures the total concentration of DO that will be demanded as organic matter degrades in a stream. It is presumed that maintaining BOD loads will maintain the low frequency of DO excursions under certain critical flow conditions. Therefore, any allocation of wasteloads and loads will be made in terms of BOD reductions. Since the watershed currently supports aquatic life, allocations relate to the BOD levels seen in the Fall River system at site 575 relative to the historic data at the site for the critical lower flow conditions (0 - 11 cfs). Based on this relationship, BOD loads at site 575 need to be maintained at the historic level so that in stream average BOD is 2.6 mg/L or less. Additional monitoring over time may be needed to further ascertain the relationship between BOD contributions of non-point sources, flow conditions, and DO levels along the stream.

For this phase of the TMDL the average condition is considered across the seasons to establish goals of the endpoint and desired reductions. Therefore, the target average BOD level was multiplied by the average daily flow for the Fall River across all hydrologic conditions. This is represented graphically by the integrated area under the BOD load duration curve established by

this TMDL. The area is segregated into allocated areas assigned to point sources (WLA) and nonpoint sources (LA). Future growth in wasteloads should be offset by reductions in the loads contributed by nonpoint sources. This offset, along with appropriate limitations, is expected to maintain this watersheds current level of full support of aquatic life. This TMDL represents the "Best Professional Judgment" as to the expected relationship between physical factors, organic matter and DO.

**Point Sources**: Point sources are responsible for maintaining their systems in proper working condition and appropriate capacity to handle anticipated wasteloads of their respective populations. The State and NPDES permits will continue to be issued on 5 year intervals, with inspection and monitoring requirements and conditional limits on the quality of effluent released from these facilities. Ongoing inspections and monitoring of the systems will be made to ensure that minimal contributions have been made by this source.

Based upon the preceding assessment, only the discharging point source (Eureka) contributing a BOD load in the Fall River watershed upstream of site 575 will be considered in this Wasteload Allocation.

Streeter-Phelps analyses for the point source indicates the present BOD permit limit (30 mg/L) for it maintains DO levels above 5 mg/L in the stream when there is no flow upstream of the discharge point (see attached Streeter-Phelps analysis).

The design flow of the point source (0.44 cfs) redefines the lowest flow seen at site 575 (90-99% exceedance), and the WLA equals the TMDL curve across this flow condition (**Figure 6**).

From this, the WLA for the city of Eureka is 70.8 lbs/day BOD which translates to an instream WLA of 6.2 lbs/day BOD at Site 575 (**Figure 6**).

**Non-Point Sources:** Based on the prior assessment of sources, the distribution of excursions from water quality standards at site 575 and the relationship of those excursions to runoff conditions and seasons, non-point sources may also be seen as a contributing factor to the occasional DO excursions in the watershed.

The samples from the Fall River watershed show there were no DO violations at flows in excess of 11 cfs. The Load Allocation assigns responsibility for maintaining the in stream BOD historic levels at site 575 to 2.6 mg/L across the 0.44 - 11 cfs range of the critical flow condition (68 - 89% exceedance) and maintaining the in stream BOD levels at site 575 to the historical levels of 5.0 mg/L for flows in excess of 11 cfs (which is $90^{th}$ percentile of BOD samples for flows in the Fall River above 11 cfs near Climax). The LA equals zero for flows from 0 - 0.44 cfs (90 - 99% exceedance), since the flow at this condition is entirely effluent created, and then increases to the TMDL curve with increasing flow beyond 0.44 cfs (**Figure 6**). Sediment control practices such as buffer strips and grassed waterways should be preserved to help maintain the non-point source BOD load under higher flows as well as the oxygen demand exerted by the sediment transported to the stream that may occur during the critical flow period.

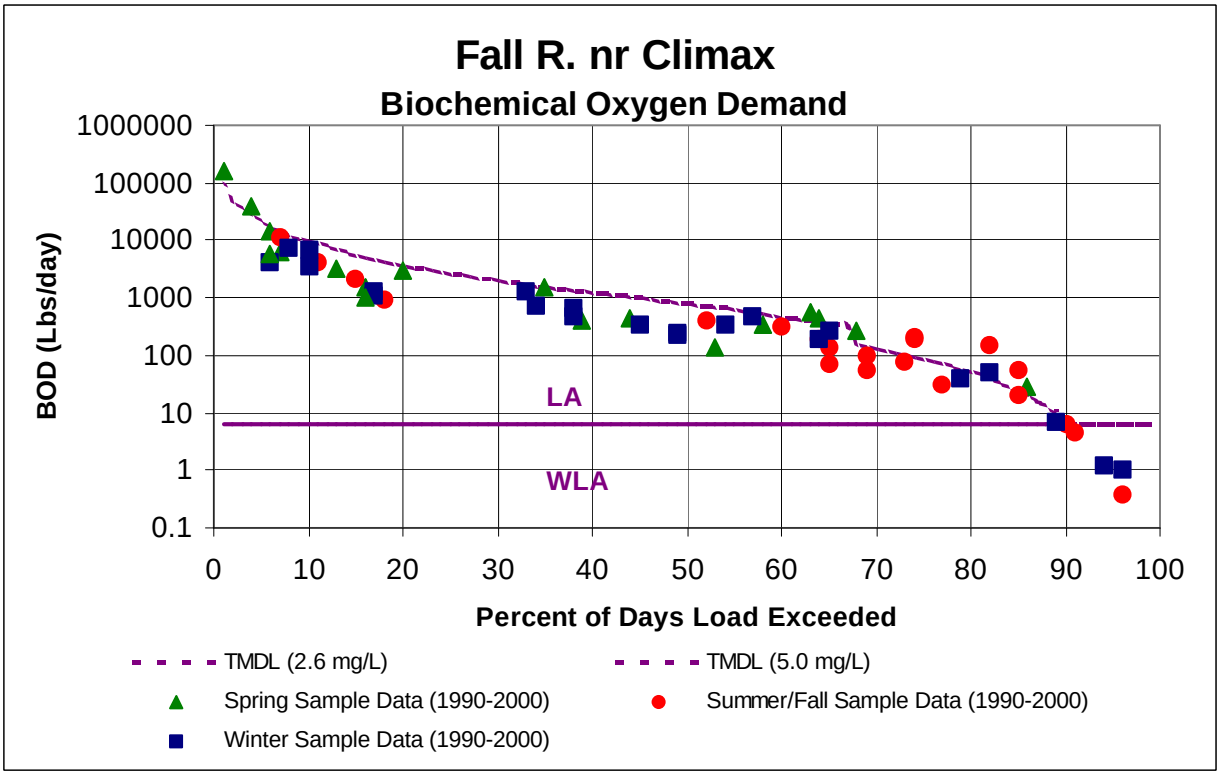



**Figure 6**

**Defined Margin of Safety:** The Margin of Safety will be implied based on conservative assumptions used in the permitting of the point source discharges including coincidence of low flow with maximum discharge from the treatment plant, associated CBOD content, temperature of the effluent, higher than expected stream velocity and the better than permitted performance of the treatment plant in producing effluent with BOD well below permit limits under critical seasonal conditions. Additionally, the target BOD concentration has been set at a conservative value since sampling data indicates exceeding this value has seldom led to a dissolved oxygen violation.

**State Water Plan Implementation Priority:** Because of this watershed's low frequency of excursion from the water quality standard, this TMDL will be a Medium Priority for implementation.

**Unified Watershed Assessment Priority Ranking:** This watershed lies within the Fall River Basin (HUC 8: 11070102) with a priority ranking of 50 (Low Priority for restoration work).

**Priority HUC 11s and Stream Segments**: Unless impairment is determined by additional monitoring between 2003- 2007, no priority HUCs or stream segments will be identified.

## 5. IMPLEMENTATION

### Desired Implementation Activities

1. None, unless impairment is determined by additional monitoring between 2003- 2007.

### Implementation Programs Guidance

Unless impairment is determined by additional monitoring between 2003- 2007, no direction is needed on implementation programs.

**Time frame for Implementation:** Conditions will be evaluated based on additional monitoring between 2003- 2007.

**Targeted Participants:** None, until 2007 evaluation.

**Milestone for 2007**: The year 2007 marks the mid-point of the ten year implementation window for the watershed. At that point in time, additional monitoring data from Station 575 will be reexamined to confirm the impaired status of the streams within this watershed. Should the case of impairment develop, source assessment, allocation and implementation activities will ensue.

**Delivery Agents**: None at this time. Status will be re-evaluated in 2007.

**Reasonable Assurances:**

**Authorities:** The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.

2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

3. K.A.R. 28-16-69 to -71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

4. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

5. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control non-point source pollution.

6. K.S.A. 82a-901, *et seq*. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

7. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan.*

8. The *Kansas Water Plan* and the Verdigris Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

**Funding**: The State Water Plan Fund, annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL is a Medium Priority consideration.

**Effectiveness:** Current point source controls appear effective in maintaining low BOD levels in wastewater discharged to streams. Current non-point sources of BOD loading to streams can be maintained through continued use of appropriate management and control systems for livestock waste and on-site waste systems within the wateshed.

## 6. MONITORING

KDHE will continue to collect bimonthly samples at Station 575 including dissolved oxygen samples. Based on that sampling, the priority status of 303(d) listing will be evaluated in 2006. Should impaired status develop, the desired endpoints under this TMDL may be refined and more intensive sampling may need to be conducted under specified seasonal flow conditions over the period 2007-2011.

Monitoring of BOD levels in effluent will be a condition of NPDES and state permits for facilities. This monitoring will continually assess the functionality of the systems in reducing nutrient levels in the effluent released to the streams.

## 7. FEEDBACK

**Public Meetings:** Public meetings to discuss TMDLs in the Verdigris Basin were held January 23 in Fredonia and March 6, 2002 in Neodesha. An active Internet Web site was established at http://www.kdhe.state.ks.us/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Verdigris Basin.

**Public Hearing:** A Public Hearing on the TMDLs of the Verdigris Basin was held in Neodesha on June 4, 2002.

**Basin Advisory Committee:** The Verdigris Basin Advisory Committee met to discuss the TMDLs in the basin on October 3, 2001, January 23 and March 6, 2002.

**Milestone Evaluation**: In 2007, evaluation will be made as to the degree of impairment which has occurred within the watershed and current condition of the Fall River. Subsequent decisions will be made regarding the implementation approach and follow up of additional implementation in the watershed.

**Consideration for 303(d) Delisting**: The stream will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2007-2011. Therefore, the decision for delisting will come about in the preparation of the 2012 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

**Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process:** Under the current version of the Continuing Planning Process, the next anticipated revision will come in 2003 which will emphasize implementation of TMDLs. At that time, incorporation of this TMDL will be made into both documents. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2003-2007.

# Appendix (Fall River DO TMDL)

**Table 2**

| Fall River Watershed (575) | | | Otter Creek Wtrshd (574) | | |
|---|---|---|---|---|---|
| Land Use | Acres | % of Total | Land Use | Acres | % of Total |
| Cropland | 6874 | 3.2 | Cropland | 4394 | 5.6 |
| Grassland | 198561 | 92.8 | Grassland | 69690 | 89.1 |
| Urban Use | 1053 | 0.5 | Urban Use | 0 | 0.0 |
| Water | 2532 | 1.2 | Water | 609 | 0.8 |
| Woodland | 4876 | 2.3 | Woodland | 3496 | 4.5 |
| Total | 213897 | 100 | Total | 78190 | 100 |

**Table 3**

| COL_DATE | DISOXY | | AMMONIA | | BOD | | FECCOLI | | NITRATE | | PHFIELD | | TEMP_CENT | | PHOSPHU | | TSS | | TURBIDITY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 |
| 4/11/90 | 9.3 | 9.7 | 0.010 | 0.010 | 4.20 | 0.01 | 1300 | 200 | 0.19 | 0.23 | 8.1 | 8.1 | 10 | 11 | 0.100 | 0.020 | 114 | 17 | 50.0 | 8.4 |
| 6/13/90 | 6.4 | 6.0 | 0.000 | 0.000 | 1.60 | 2.10 | 400 | 400 | 0.47 | 0.43 | 8.1 | 8.1 | 25 | 25 | 0.070 | 0.050 | 48 | 52 | 22.0 | 25.2 |
| 8/15/90 | 6.4 | 7.0 | 0.030 | 0.010 | 2.00 | 3.00 | 1100 | 180 | 0.41 | 0.18 | 8.0 | 8.1 | 22 | 22 | 0.130 | 0.060 | 78 | 31 | 47.0 | 19.6 |
| 10/10/90 | 8.0 | 7.8 | 0.020 | 0.030 | 2.40 | 3.10 | 80 | 60 | 0.05 | 0.03 | 7.9 | 8.0 | 11 | 11 | 0.020 | 0.030 | 20 | 14 | 15.0 | 12.0 |
| 12/5/90 | 11.1 | 10.7 | 0.000 | 0.000 | 1.80 | 2.90 | 40 | 10 | 0.01 | 0.00 | 8.3 | 8.3 | 2 | 2 | 0.020 | 0.020 | 7 | 5 | 4.5 | 3.7 |
| 3/13/91 | 8.7 | 9.2 | 0.020 | 0.020 | 2.90 | 3.20 | 50 | 10 | 0.01 | 0.02 | 8.1 | 8.2 | 6 | 7 | 0.060 | 0.030 | 19 | 17 | 10.3 | 10.4 |
| 5/15/91 | **4.2** | 6.3 | 0.000 | 0.000 | 4.80 | 4.70 | 80 | 80 | 0.04 | 0.04 | 7.9 | 8.1 | 22 | 22 | 0.130 | 0.070 | 38 | 33 | 23.0 | 19.0 |
| 7/31/91 | 6.0 | 5.0 | 0.000 | 0.000 | 6.10 | 4.40 | 100 | 100 | 0.05 | 0.24 | 8.2 | 7.9 | 24 | 24 | 0.120 | 0.110 | 37 | 51 | 18.2 | 36.9 |
| 9/11/91 | 5.1 | 4.2 | 0.000 | 0.000 | 2.40 | 2.80 | 100 | 100 | 0.10 | 0.11 | 8.1 | 7.9 | 26 | 25 | 0.050 | 0.060 | 11 | 17 | 9.2 | 12.1 |
| 2/12/92 | 11.3 | 11.3 | 0.000 | 0.000 | 1.80 | 2.50 | 40 | 70 | **11.30** | 0.13 | 4.3 | 8.1 | 3 | 3 | 0.050 | 0.050 | 7 | 13 | 4.8 | 7.9 |
| 4/15/92 | 8.0 | 7.6 | 0.050 | 0.050 | 2.10 | 2.00 | 80 | 100 | 0.02 | 0.03 | 8.3 | 8.2 | 18 | 19 | 0.060 | 0.050 | 31 | 19 | 15.2 | 12.0 |
| 6/10/92 | 6.4 | 6.5 | 0.070 | 0.050 | 7.40 | 6.20 | 20000 | 25000 | 0.27 | 0.42 | 6.5 | 7.7 | 19 | 19 | 0.890 | 0.800 | 1099 | 976 | 346.0 | 464.0 |
| 8/5/92 | 7.5 | 6.9 | 0.050 | 0.050 | 2.00 | 2.20 | 4000 | 1800 | 0.08 | 0.26 | 8.1 | 7.9 | 21 | 20 | 0.200 | 0.150 | 215 | 96 | 69.0 | 58.6 |
| 10/7/92 | 8.2 | 8.0 | 0.050 | 0.050 | 3.40 | 2.46 | 80 | 100 | 0.02 | 0.14 | 8.2 | 7.9 | 16 | 15 | 0.060 | 0.050 | 24 | 21 | 11.4 | 9.3 |
| 12/9/92 | 12.6 | 12.2 | 0.050 | 0.050 | 1.20 | 1.70 | 350 | 100 | 0.34 | 0.54 | ----- | ----- | 1 | 2 | 0.070 | 0.050 | 19 | 27 | 11.5 | 20.0 |
| 3/10/93 | 10.7 | 10.8 | 0.050 | 0.050 | 1.20 | 1.10 | 10 | 30 | 0.29 | 0.38 | 8.2 | 8.2 | 7 | 7 | 0.050 | 0.050 | 25 | 19 | 9.0 | 5.0 |
| 5/5/93 | 8.8 | 8.6 | 0.050 | 0.050 | 2.10 | 1.20 | 3800 | 460 | 0.31 | 0.42 | 8.1 | 8.0 | 15 | 15 | 0.170 | 0.060 | 180 | 76 | 68.0 | 26.0 |
| 7/14/93 | 6.8 | 6.6 | 0.050 | 0.050 | 2.30 | 3.60 | 6100 | 60000 | 0.40 | 0.56 | 8.3 | 8.0 | 25 | 24 | 0.150 | 0.190 | 120 | 88 | 46.0 | 29.0 |
| 9/15/93 | 7.6 | 7.6 | 0.050 | 0.050 | 1.80 | 1.70 | 100 | 100 | 0.42 | 0.67 | 8.0 | 7.9 | 15 | 15 | 0.090 | 0.080 | 30 | 20 | 18.0 | 10.0 |
| 11/10/93 | 11.5 | 9.6 | 0.050 | 0.050 | 3.90 | 4.00 | 10 | 10 | 0.12 | 0.27 | 8.0 | 7.7 | 4 | 4 | 0.080 | 0.050 | 10 | 11 | 4.0 | 4.0 |
| 4/13/94 | 10.5 | 10.3 | 0.050 | 0.050 | 4.10 | 3.30 | 17000 | 1500 | 0.26 | 0.39 | 8.1 | 7.9 | 7 | 7 | 0.190 | 0.070 | 188 | 62 | 99.0 | 34.0 |
| 6/14/94 | 6.6 | 6.8 | 0.050 | 0.050 | 3.40 | 3.20 | 100 | 2300 | 0.21 | 0.29 | 7.8 | 8.0 | 24 | 23 | 0.060 | 0.050 | 32 | 22 | 12.0 | 8.0 |
| 8/10/94 | 6.0 | 7.6 | 0.010 | 0.010 | 5.50 | 9.40 | 70 | 400 | 0.05 | 0.11 | 8.1 | 8.0 | 24 | 23 | 0.070 | 0.080 | 38 | 34 | 11.0 | 9.0 |
| 10/12/94 | 5.7 | 5.8 | 0.010 | 0.010 | 2.80 | 3.30 | 2100 | 500 | 0.01 | 0.01 | 7.7 | 7.8 | 12 | 12 | 0.010 | 0.010 | 11 | 17 | 6.0 | 7.0 |
| 12/7/94 | 11.0 | 10.5 | 0.110 | 0.060 | 4.30 | 3.90 | 60 | 20 | 0.36 | 0.40 | 8.1 | 7.9 | 3 | 2 | 0.040 | 0.010 | 12 | 9 | 4.0 | 4.0 |
| 1/19/95 | 12.9 | 11.9 | 0.010 | 0.010 | 2.60 | 1.70 | 10 | 100 | 0.20 | 0.17 | 8.2 | 8.1 | 1 | 2 | 0.010 | 0.010 | 2 | 2 | 2.0 | 2.0 |
| 3/22/95 | 9.1 | 8.9 | 0.010 | 0.010 | 2.40 | 1.40 | 60 | 100 | 0.20 | 0.17 | 8.2 | 8.1 | 14 | 14 | 0.060 | 0.040 | 43 | 22 | 8.0 | 6.0 |
| 5/17/95 | 7.0 | 8.0 | 0.210 | 0.120 | 10.10 | 7.60 | 60000 | 60000 | 0.28 | 0.25 | 7.7 | 7.6 | 17 | 17 | 1.850 | 1.410 | 1970 | 1360 | 185.0 | 157.0 |
| 7/19/95 | 6.5 | 6.8 | 0.020 | 0.010 | 2.90 | 2.40 | 400 | 100 | 0.71 | 0.34 | 7.9 | 7.9 | 25 | 24 | 0.090 | 0.060 | 78 | 31 | 15.0 | 13.0 |
| 9/20/95 | 7.3 | 7.5 | 0.520 | 0.230 | 2.00 | 2.00 | 20 | 500 | 0.42 | 0.55 | 8.0 | 7.9 | 17 | 17 | 0.045 | 0.041 | 26 | 22 | 10.0 | 8.0 |
| 11/15/95 | 10.5 | 11.4 | 0.032 | 0.036 | 3.80 | 1.20 | 100 | 10 | 0.01 | 0.15 | 7.9 | 7.8 | 5 | 5 | 0.019 | 0.013 | 9 | 7 | 3.0 | 2.0 |
| 2/21/96 | 13.8 | 11.5 | 0.138 | 0.054 | 3.30 | 3.20 | 7 | 1 | 0.30 | 0.25 | 7.9 | 7.7 | 4 | 4 | 0.037 | 0.035 | 8 | 15 | 2.8 | 6.1 |
| 4/17/96 | 9.5 | 10.0 | 0.070 | 0.028 | 3.90 | 5.10 | 6 | 100 | 0.03 | 0.06 | 8.1 | 8.1 | 13 | 12 | 0.030 | 0.030 | 13 | 18 | 6.0 | 5.0 |
| 6/19/96 | 6.6 | 4.8 | 0.160 | 0.083 | 5.90 | 3.30 | 26000 | 1000 | 0.64 | 0.26 | 7.5 | 7.6 | 19 | 22 | 0.800 | 0.208 | 660 | 128 | 375.0 | 96.0 |
| 8/14/96 | 7.7 | 9.6 | 0.040 | 0.120 | 9.50 | 7.50 | 30 | 50 | 0.06 | 0.01 | 8.1 | 8.1 | 22 | 22 | 0.147 | 0.095 | 36 | 38 | 11.0 | 14.0 |
| 10/9/96 | 9.0 | 7.8 | 0.300 | 0.308 | 5.90 | 6.00 | 190 | 300 | 0.10 | 0.08 | 8.2 | 8.0 | 14 | 14 | 0.070 | 0.070 | 36 | 37 | 12.0 | 17.0 |
| 12/4/96 | 13.0 | 13.0 | 0.020 | 0.020 | 3.00 | 3.10 | 9110 | 400 | 0.20 | 0.26 | 8.1 | 8.0 | 4 | 4 | 0.080 | 0.078 | 49 | 20 | 27.0 | 30.0 |
| 1/8/97 | 13.2 | 12.6 | 0.020 | 0.020 | 1.44 | 1.00 | 100 | 50 | 0.08 | 0.15 | 8.1 | 8.0 | 3 | 4 | 0.020 | 0.012 | 2 | 2 | 2.2 | 2.7 |
| 3/5/97 | 11.5 | 11.3 | 0.020 | 0.020 | 1.38 | 1.00 | 130 | 30 | 0.25 | 0.32 | 8.2 | 7.9 | 6 | 6 | 0.040 | 0.020 | 17 | 10 | 10.0 | 5.0 |
| 5/7/97 | 8.1 | 8.4 | 0.020 | 0.020 | 5.10 | 2.16 | 50 | 40 | 0.12 | 0.19 | 7.9 | 7.9 | 19 | 18 | 0.010 | 0.010 | 7 | 8 | 3.3 | 3.3 |
| 7/9/97 | 6.5 | 6.2 | 0.040 | 0.020 | 3.81 | 2.91 | 22000 | 2300 | 0.36 | 0.13 | 7.7 | 7.8 | 24 | 25 | 0.430 | 0.319 | 224 | 260 | 102.0 | 86.0 |
| 9/10/97 | **3.9** | 6.8 | 0.020 | 0.020 | 1.17 | 1.14 | 20 | 300 | 0.11 | 0.25 | 7.5 | 7.7 | 23 | 22 | 0.060 | 0.050 | 17 | 15 | 14.0 | 13.0 |
| 11/5/97 | **3.3** | 8.2 | 0.020 | 0.020 | 1.83 | 2.67 | 90 | 110 | 0.07 | 0.11 | 8.0 | 7.8 | 9 | 9 | 0.040 | 0.060 | 9 | 11 | 4.0 | 5.4 |
| 2/4/98 | 12.1 | 11.7 | 0.020 | 0.020 | 1.74 | 1.08 | 70 | 20 | 0.17 | 0.17 | 8.0 | 8.1 | 4 | 4 | 0.010 | 0.010 | 7 | 7 | 4.7 | 3.4 |
| 4/8/98 | 8.4 | 9.9 | 0.090 | 0.020 | 1.50 | 1.35 | 210 | 390 | 0.15 | 0.16 | 8.3 | 8.1 | 13 | 13 | 0.038 | 0.034 | 22 | 19 | 10.0 | 10.0 |
| 6/3/98 | 6.1 | 7.9 | 0.020 | 0.020 | 1.05 | 1.32 | 70 | 230 | 0.38 | 0.24 | 7.9 | 7.9 | 27 | 26 | 0.060 | 0.050 | 24 | 20 | 11.0 | 9.0 |
| 8/5/98 | 6.8 | 4.9 | 0.020 | 0.030 | 1.00 | 1.77 | 1000 | 1300 | 0.39 | 0.39 | 8.1 | 7.7 | 26 | 25 | 0.120 | 0.100 | 50 | 46 | 27.0 | 32.0 |
| 10/7/98 | 8.8 | 7.8 | 0.020 | 0.020 | 1.11 | 1.26 | 1700 | 390 | 0.24 | 0.34 | 8.1 | 7.9 | 17 | 17 | 0.081 | 0.067 | 52 | 34 | 31.0 | 21.0 |
| 12/9/98 | 10.9 | 11.0 | 0.050 | 0.020 | 3.60 | 3.90 | 2500 | 2100 | 0.40 | 0.39 | 8.0 | 7.8 | 8 | 8 | 0.070 | 0.050 | 32 | 15 | 18.0 | 9.0 |
| 3/1/99 | 11.6 | 10.8 | 0.020 | 0.040 | 2.34 | 2.34 | 10 | 30 | 0.28 | 0.23 | 8.1 | 8.0 | 11 | 11 | 0.030 | 0.030 | 7 | 8 | 3.2 | 3.0 |
| 5/3/99 | 8.7 | 8.8 | 0.020 | 0.020 | 1.02 | 1.00 | 140 | 180 | 0.53 | 0.34 | 8.1 | 8.1 | 17 | 18 | 0.060 | 0.030 | 23 | 11 | 11.0 | 5.0 |
| 6/28/99 | 7.0 | 6.9 | 0.020 | 0.020 | 1.59 | 1.71 | 3100 | 3700 | 0.43 | 0.55 | 8.0 | 7.9 | 26 | 25 | 0.100 | 0.140 | 70 | 114 | 37.0 | 55.0 |
| 8/30/99 | 6.6 | 7.3 | 0.020 | 0.020 | 1.00 | 1.00 | 50 | 30 | 0.67 | 0.35 | 7.7 | 7.7 | 26 | 26 | 0.050 | 0.040 | 26 | 20 | 9.0 | 9.0 |
| 11/1/99 | 8.4 | 6.5 | 0.020 | 0.020 | 2.58 | 3.72 | 150 | 2400 | 0.18 | 0.06 | 8.0 | 7.8 | 16 | 16 | 0.066 | 0.074 | 7 | 12 | 3.3 | 4.8 |
| 1/31/00 | 14.2 | 13.5 | 0.020 | 0.020 | 1.56 | 1.26 | 10 | 10 | 0.48 | 0.37 | 8.2 | 8.1 | 2 | 2 | 0.040 | 0.020 | 8 | 4 | 3.4 | 2.3 |
| 4/3/00 | 10.1 | 10.2 | 0.020 | 0.020 | 2.25 | 2.31 | 40 | 80 | 0.22 | 0.16 | 8.2 | 8.2 | 13 | 12 | 0.030 | 0.030 | 15 | 16 | 6.5 | 6.2 |
| 6/5/00 | 9.6 | 8.5 | 0.020 | 0.020 | 7.41 | 3.15 | 60 | 50 | 0.07 | 0.25 | 7.8 | 8.1 | 24 | 23 | 0.100 | 0.050 | 38 | 23 | 6.8 | 4.8 |
| 8/7/00 | 6.7 | 7.6 | 0.020 | 0.020 | 2.67 | 2.85 | 60 | 180 | 0.69 | 0.34 | 7.8 | 7.8 | 28 | 28 | 0.040 | 0.050 | 22 | 13 | 10.5 | 6.7 |
| 10/2/00 | 8.3 | 8.6 | 0.020 | 0.020 | 2.61 | 3.99 | 30 | 40 | 0.10 | 0.12 | 7.9 | 7.8 | 19 | 19 | 0.032 | 0.033 | 5 | 14 | 5.0 | 6.0 |
| 11/27/00 | 12.2 | 11.9 | 0.030 | 0.020 | 1.74 | 1.00 | 20 | 10 | 0.48 | 0.50 | 7.9 | 7.9 | 5 | 5 | 0.050 | 0.020 | 6 | 8 | 3.0 | 2.1 |
| Avg | 8.7 | 8.7 | 0.049 | 0.038 | 3.07 | 2.81 | 3078 | 2838 | 0.43 | 0.25 | 7.9 | 7.9 | 15 | 15 | 0.129 | 0.094 | 101 | 69 | 32.11 | 25.27 |

**Table 4**

| COL_DATE | DISOXY | | AMMONIA | | BOD | | FECCOLI | | NITRATE | | PHFIELD | | TEMP_CENT | | PHOSPHU | | TSS | | TURBIDITY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 | 575 | 574 |
| 5/15/91 | **4.2** | 6.3 | 0.000 | 0.000 | 4.80 | 4.70 | 80 | 80 | 0.04 | 0.04 | 7.9 | 8.1 | 22 | 22 | 0.130 | 0.070 | 38 | 33 | 23.0 | 19.0 |
| 9/10/97 | **3.9** | 6.8 | 0.020 | 0.020 | 1.17 | 1.14 | 20 | 300 | 0.11 | 0.25 | 7.5 | 7.7 | 23 | 22 | 0.060 | 0.050 | 17 | 15 | 14.0 | 13.0 |
| 11/5/97 | **3.3** | 8.2 | 0.020 | 0.020 | 1.83 | 2.67 | 90 | 110 | 0.07 | 0.11 | 8.0 | 7.8 | 9 | 9 | 0.040 | 0.060 | 9 | 11 | 4.0 | 5.4 |
| Avg | 3.8 | 7.1 | 0.013 | 0.013 | 2.60 | 2.84 | 63 | 163 | 0.07 | 0.13 | 7.8 | 7.9 | 18 | 18 | 0.077 | 0.060 | 21 | 20 | 13.67 | 12.47 |

# Streeter-Phelps DO Sag Model - FallRDO_Eureka
## Single Reach - Single Load

1 cfs = .0283 $m^3/s$

0.25 mph =0 .11176 m/s

0.0123699 Design Flow (Eureka)

| | Elev (ft) | Dist to 607 | Min DO | Crit Dist DO |
|---|---|---|---|---|
| | 1020 | 11.10 | 5.25 | 10.58 |

**Elevation Correction (DO)**

| | | |
|---|---|---|
| Elevation | **1020** | ft |
| Correctn Factor ($DO_{sat}$) | 0.96736 | mg/L |

Unless modified by upstream pt. source, upstream BOD set as target for basin
Upstream DO (where appropriate) elevation corrected and set at 90% sat.

Distance (km)
Flow ($m^3/s$)
Concentration (mg/L)
Temp ( C )
Vel (m/s)

| | | | |
|---|---|---|---|
| Velocity | 0.11176 | | |
| BOD coef | 0.23 | Theta | 1.056 |
| O2 coef | 1.68 | Theta | 1.024 |

| | | Flow | BOD | DO | T | Dist | Slope (ft.mi) | Calc $K_r$ | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **Eureka** | 0.0123700 | 30 | 7.21 | 21.6 | 10.7 | 6.38 | 1.68 | |
| | Upstream | 0 | 0 | 0 | 0 | ----- | | | |
| | Result at Dist (Site 575) | 0.01237 | 22.48 | 5.25 | 23.3 | | | | Elev = 975 ft |

**Kr Values (Foree 1977) using** 0.42 (0.63 + 0.4S^1.15)
for q < 0.05 where q = $cfs/mi^2$ and S (ft/mile)